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Site-Specific Development Plan

Carlin, Nevada

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Summary and Conclusions

The conditions for developing the geothermal resource near Carlin appear favorable. The resource has a favorable temperature range for direct applications (174°F or 79°C), the geothermal fluid has low total dissolved solids, no objectionable constituents that would result in costly scaling or corrosion problems and the resource is conveniently located within two miles from town.

Direct space heating is the most realistic application and is recommended. Several clusters of homes are located less than 2 miles away. The project could be developed on a larger scale than this study proposes. The engineering and economic models are proposed on a small scale here for simplicity in evaluating the feasibility of pursuing development. Conceivably the producing well will provide sufficient hot water to accommodate more homes than the models include.

The town of Carlin seems receptive to development and there does not appear to be any major barriers to exploration or development. The regulatory climate in both the state and county is conducive to geothermal development at this level. No major regulatory or environmental obstacles are noted which would severely curtail utilization for space heating.

The prospect of replacing natural gas heat with geothermal heat for 60 or more homes is economically attractive. Geothermal rates for hot water are not expected to increase as rapidly as the price of natural gas to the consumer over the next 10 years. The increases for hot water from geothermal are primarily a function of power costs for the pumps plus inflation affecting maintenance costs. Individual homeowners can expect payback on retrofitting costs within two to three years.

The project is technologically viable at the present time.

It is recommended that steps be taken in the near future to initiate development of the Carlin Hot Springs geothermal resource.

Introduction

The goal of the Site Specific Development Plan for Carlin is to investigate the near term potential for utilization of geothermal resources located near Carlin, Nevada, and then to make recommendations as to how the resource can be most effectively developed. The overall objective of the study is to inform local, county and state individuals about the feasibility of exploring the resource, offering helpful guidelines for exploration and development options along with a review of legal, environmental and financial aspects which may affect direct applications.

The study is sponsored and funded by the Nevada Department of Energy (NDOE). Questions may be directed to NDOE, Carson City, Nevada.

1.0 Background

1.1 Location

The Carlin study area is located in Elko County, Nevada, 20 miles southwest of the city of Elko. The town of Carlin is located near the Humboldt River, essentially in the southeast quarter of Section 27, T33N, R52E, some 5 miles north-northwest of the termination of the Carlin-Pinyon Range. Buckskin Mountain (6,690 ft) and Spring Canyon Mountain (7,368 ft) are the two highest elevations in this range. Swales Mountain (8,080 ft elevation) is located 10 miles almost due north of Carlin, and Fish Creek Mountain (7,400 ft) is approximately 15 miles north of the town, both being in the north-south trending Independence Range. Mary's Mountain, with a maximum elevation of 7,700 ft, is located approximately 6 to 8 miles west-northwest of the town. The valley floor in which Carlin is located lies at an elevation of 4,953 ft above sea level.

Two transcontinental railroad lines, the Southern Pacific and Western Pacific Railroads, pass through Carlin. U.S. Highway 80, U.S. Highway 40 and State Highway 20 all pass through the urban area. United Air Lines and Air Chapparral, a Reno commuter line, serve nearby Elko. The town boundaries encompass 9 square miles of urban development and rural agricultural land.

Figure 1-1 illustrates the location of Carlin. Topographic features of the study area are graphically displayed in the aerial photo (Figure 1-2) and topographic map (Figure 1-3). The Carlin 1:62,500 USGS AMS topographic quadrangle map encompasses the entire study area. A layout of the town of Carlin is shown in Figure 1-4.

1.2 Demographics

1.2.1 Population

Preliminary 1980 census figures show Carlin has a population of 1,264, a decrease from 1970 when the population was 1,356 persons. However, there was an upward swing to nearly 1,300 persons in November, 1980. Young people leaving the area for school and/or employment elsewhere account for the majority of the population decrease. The current population falls short of the projections made by the Carlin Citizens Advisory Committee in 1971. It was anticipated that population would increase to at least 1,470 and as high as 1,685. The optimistic increase was expected to result from a growth spillover from Elko after the U.S. Highway 80 link was completed in 1973. The historical growth pattern of Carlin compared to Elko County growth is shown in Table 1-1.

Figure 1-1 Location of Study Area, from Nevada Fact Book

Figure 1-2 Aerial Photographic View of the Greater Carlin Area

0 Scale 5,200 ft

Figure 1-3 Carlin 15 min. AMS Topographic Quadrangle. From U.S. Geological Survey, Denver, Colorado, 1952

Figure 1-4 Map of Carlin's Urbanized Area, from Chilton Engineering, Consulting Engineers, Elko, Nevada

Table 1-1 Comparison of Carlin and Elko County Population Growth

	1930	1940	1950	1960	1970	1980 (Est.)
Carlin	825	832	1,203	1,023	1,356	1,264
Elko County	9,960	10,912	11,654	12,011	13,958	17,409

1930-1970 Figures From Gordon, 1971

1980 Figures From U.S. Census Data

1.2.2 Industries

The employment distribution by industry in 1971 is shown by Table 1-2.

Table 1-2 Estimated Employment Distribution

Labor Force Element	1971		1980 (Est.)	
	No.	Percent	No.	Percent
Retail Trade & Personal Service	130	35.0	108	22.0
Railroads	120	32.0	100	21.0
Mining	100	27.0	250	52.0
Government Service	20	6.0	15	2.0
Road Construction	0	0.0	10	5.0
Estimated Total	370	100.0	483	100.0

1971 Figures From Gordon, 1971

At the present time, mining employs 52 percent of the labor force while railroading, retail trades and ranching account for 43 percent, and road construction and government service account for the balance of 5 percent.

The principal mining operations are the Eisman Chemical Company, which mines and processes barite, the Carlin Gold Mine (located 10 miles north of town), and the Cortez Mining Company which operates the Cortez Gold Mine located 23 miles southwest of Carlin. The retail trade breakdown is given in Table 1-3.

Table 1-3 Retail Trade Breakdown

Business Service	Total		Estimated Employees Per Unit		Total Employment	
	1971	1980	1971	1980	1971	1980
Motels	3	1	4	4	12	4
Gas Stations	—	2	—	4	—	8
Service Garage	4	2	3	2	12	4
Restaurants	7	5	5	8	30	40
Bars	5	5	3	3	15	15
Barber Shops	2	—	1	—	2	—
Beauty Parlors	1	1	2	2	2	2
Branch Bank	1	1	5	2	5	2
Grocery	2	2	5	6	10	12
Appliance Shop	1	—	4	—	4	—
Total					92	87
Government (City)	—	—	20	15	20	15
Services (County)	2	—	25	25	25	25
Total	29	19			137	127

Note: The gross annual 1971 payroll for all business and industry is estimated at \$3,564,000. Current annual payroll is estimated to be \$4,469,000 (1971 dollars).

1971 Figures From Gordon, 1971. 1980 Figures are best estimates, Town Clerk.

The total employment figure estimate in 1971, as shown in Table 1-2, was 370 (excluding pensioners). At the present time, total employment is estimated to be 483.

1.2.3 Weather

Average monthly temperatures for the City of Carlin are given in Table 1-4 for the year 1979. A 30-year average is not available for Carlin, but a comparison with temperatures in Elko reveals sufficient similarity to utilize the 30-year averages for Elko as an accurate estimate for Carlin. These are presented in Table 1-5. The annual average temperature is 45 to 47°F. Calculated degree days for Carlin are given in Table 1-6.

Total annual precipitation in the lowland areas is 9 to 10 in. Greater amounts of precipitation fall on the mountains. Distribution of precipitation in Elko County is displayed in Figure 1-5.

Table 1-4 1979 Average Temperature Summary Carlin, Nevada (°F)*

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
19.4	27.9	32.3	40.8	54.0	62.3	71.0	67.3	65.9	54.5	32.7	31.6

Annual Average = 47.1°F

* Carlin Gold Mine Station, U.S. Weather Bureau Records

Table 1-5 30-Years Average Temperature Summary Elko, Nevada (°F)*

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23.3	29.4	35.0	43.5	51.8	59.6	69.6	67.0	57.5	46.9	34.8	25.8

Annual Average = 45.4°F

Highest Recorded Temperature = 102°F (1949)

Lowest Recorded Temperature = -38°F (1949)

* 1941 - 1970 - U.S. Weather Bureau Records

Table 1-6 Heating Degree Days - Carlin, Nevada

	Monthly Avg. °F	Degree Days °F
Jan	19.4	1,414
Feb	27.9	1,039
Mar	37.3	858
Apr	40.8	726
May	54.0	341
Jun	62.3	81
Jul	71.0	-186
Aug	67.3	-71
Sep	65.9	-27
Oct	54.5	325
Nov	32.7	969
Dec	31.6	1,035
Total Heating Degree F Days		6,788
Degree C Days		3,754

Figure 1-5 *Distribution of Annual Precipitation, from Granger, Bell, Simmons and Lee, 1957*

1.2.4 Local Attitudes Affecting Development of Geothermal Energy

Generally, the townspeople interviewed were very receptive to the prospects for geothermal development for the area. Carlin citizens are seeking to improve the town and would like to see a reasonably healthy growth in the area while retaining the benefits of a small town atmosphere.

1.3 Economy of Carlin

1.3.1 Economic Base by Industry

The estimated earned income by trade in 1971 is shown in Table 1-7, compared with 1980 earned income figures which show the affect of the shift to mining.

Table 1-7 Estimated Earned Income (1971 Dollars)

Labor Force Element	\$ Amt. 1971	Percent	\$ Amt. 1980	Percent
Retail Trade & Personal Service	1,200,000	33.6	997,000	22.3
Railroad	1,100,000	31.0	917,000	20.5
Mining	925,000	26.0	2,313,000	51.8
Pensioners	180,000	5.0	30,000	.7
Government Service	159,000	4.4	119,000	2.7
Road Construction	---	---	93,000	2.1
Estimated Total	3,564,000	100.0	4,469,000	100.0

1971 Figures From Gordon, 1971

1.3.2 Unemployment, Manpower Availability

Although unemployment is not a serious problem in Carlin, manpower is available for new jobs as they become available. Road construction crews are generally imported to the area, with few local people being hired. Mining continues to be an employment opportunity as mills are operated and constructed using available local laborers.

1.3.3 Potential for New Industry and Business

Carlin is steadily attracting new mining industry-related services. The increased industrial development is resulting in a demand for additional housing, businesses and schools. Presently, a new housing project is proposed for Carlin which tentatively is to consist of 6 duplexes. A new school is proposed for the area, but must first survive a bond issue on the ballot. The citizens believe

that a new school must be constructed within the next 5 years to accommodate the student population anticipated by 1985. In addition, several chain stores for drugs and groceries have been studying Carlin as an area for expansion. Presently, Carlin residents do not have their own drug store, veterinary supply facilities, or large chain supermarket, and they must travel to Elko for medical attention. Citizens are very receptive to the prospect of firms locating their expansion facilities in Carlin.

1.3.4 Local Taxes - County and City

City taxes levied are as follows:

- City room tax - 5 percent
- Business license tax - \$60/year (paid quarterly)
- Liquor tax - \$300/year (bars, restaurants, stores)
- Building permit fees
- Gaming tax (slot machines) \$15/qtr/machine plus \$5 for one table or electronic game plus \$2.50/qtr for each additional table or game.

The County taxes listed below are similar to those in other Nevada counties:

- County gasoline tax, varying percentage based on population of Carlin.
- Liquor tax, same as above.
- Ad valorem taxes, same as above.
- Cigarette tax, same as above.
- Gaming tax, same as above.
- Real property transfer tax, same as above.

1.4 Land Status

The town of Carlin consists of nine square miles, of which only 2 square miles are urbanized. Scattered ranches and mining activity dot the otherwise unoccupied rural portion of the area. Most of the retail establishments are clustered along U.S. Highway 40, and U.S. Highway 80 to a lesser extent.

Table 1-8 is a generalized land use distribution of the urbanized area as of 1971. This distribution has not changed significantly over the last ten years.

Table 1-8 Land Use Area Summary Within Urbanized Zone

Use	Area	Percent
Undeveloped	842.43	67.11
Streets	149.21	11.91
Railroad	121.67	9.71
Residence	67.23	5.41
Airport	40.00	3.21
Institutional	13.92	1.11
Business	9.00	0.71
Parks	4.13	0.33
River	4.00	0.32
Alleys	3.01	0.16
Industry	2.00	0.02
	1,256.60 Acres	100.00
(Approximately 2 sq. mi.)		

1.4.1 Bureau of Land Management Lands

In the four townships and ranges encompassing the study area, the Bureau of Land Management (BLM) controls unleased acreage as shown in Table 1-9. More than half of the sections within the four townships are BLM controlled.

1.4.2 Lease Status of BLM Lands

Oil and gas leases are held in Section 2, T32N, R53E, and Sections 2, 4, 12, 24 and 36 of T33N, R53E. There is one geothermal lease application in the study area, located in Section 8, T33N, R53E.

1.4.3 State, Private and Railroad Lands

Total sections which are controlled by the state or Central Pacific Railroad patents are given in Table 1-9. Private lands in the area are predominately from State Selection (SS) and railroad patent divestments.

The resource southwest of Carlin is located on privately owned land. Areas of interest in Section 4 and 5, T32N, R52E, are owned by the Tomera Ranch, and the south half of Section 33, T33N, R52E is owned by Melvin Jones of Carlin. The majority of these lands are from railroad patent sales with the Central Pacific Railroad retaining mineral rights.

Table 1-9 Land Status Distribution by Number of Sections within Study Area

<u>Township and Range (MDM)</u>	<u>Unleased BLM Land</u>	<u>Percent</u>	<u>Leased BLM</u>	<u>Percent</u>	<u>State Lands</u>	<u>Percent</u>	<u>RR Land</u>	<u>Percent</u>	<u>Private Land</u>	<u>Percent</u>	<u>Total Sections</u>	<u>Total Percent</u>
T32N R52E	17.0	47	—	—	1.75	5	14.5	40	2.75	8	36	100
T33N R52E	14.5	40			4.00	11	14.5	40	3.00	8	36	100
T32N R53E	17.0	47	1.0 ^(a)	3	18.00	50	—	—	—	—	36	100
T33N R53E	11.0	31	6.0 ^(b)	17	10.00	28	7.0	19	2.00	6	36	100
Totals	59.5	41	7.0	5	33.75	23	36.0	25	7.75	5	144	100

(a) Oil & Gas Lease, Sec. 2

(b) 5 Oil & Gas leases in Secs. 2, 4, 12, 24 and 36;
1 Geothermal lease application, Sec. 8

1.5 Water Resources

Cold springs located north and west of Carlin provide the water supply for the town and the Southern Pacific Railroad. The distribution systems have recently been interconnected into one public system. The town's system produces 1,180,000 gallons of water per day and the Southern Pacific Railroad system supplies approximately 500,000 gallons per day, a combined daily supply of 1,680,000 gallons. Only 870,000 gallons per day are consumed, leaving a surplus of 810,000 gallons per day. A water tank located on a hill just northwest of the town provides storage of the water supply. The chemical composition of city drinking water is given in Table 1-10. The chemical quality meets the State of Nevada Drinking Water Standards.

Table 1-10 City of Carlin Water Chemistry

	<u>PPM</u>
Ca	46.000
Mg	12.000
Na	28.000
K	8.000
SO ₄	49.000
Cl	16.000
N	2.000
HCO ₃	198.000
CO ₃	0.000
F	0.290
As	0.005
Fe	0.000
Mn	0.400
Cu	0.000
Zn	0.240
Ba	0.120
Cd	<0.001
Cr	<0.005
Pb	<0.005
Hg	<0.005
Se	<0.005
Ag	<0.005
TDS	<u>297.000</u>
Alkalinity	162.000
Hardness	164.000

Source: Bureau of Laboratories and Research,
Nevada Division of Health, Reno, July, 1980
Analysis

2.0 Resource Evaluation

2.1 Description of Resources

Three geothermal spring systems are located in the study area. Two springs are on private land within 3 miles southwest of the urbanized area. The third system is almost 5 miles to the northeast of the town on state land. All three systems lie on a trend bearing N40E, but based on presently available data, it is not reasonable to infer that they are related.

2.1.1 Hot Springs SW of Carlin

These springs are known in the literature as "Springs near Carlin." There are two groups in this category, the nearest being in Section 33, T33N, R52E (SWSWSE) near the Humboldt River (Figure 2-1), adjacent to State Highway 20, less than 2 miles from town. Some of the pools are located in the river and along the banks. In 1957, Smith (1976) measured a temperature of 151°F (66°C) in the bubbling pool located farthest from the river, adjacent to the highway. In 1973, Mariner and others (1974) sampled the fluids and recorded an on-site surface water temperature of 174°F (79°C). A private engineering firm measured a temperature of 187°F (86°C) in 1978. Results of the chemical analysis are given in Table 2-1. The published flow measurement indicates a fluid discharge rate of 300 gallons per minute (GPM).

Drilling records of domestic water wells in Section 33 indicate warm to hot water (130°F or 54°C) is encountered at approximately 200 ft in loose limey gravels. The water quality is described as "poor to fair, with sulfur present." These waters are dominantly calcium-bicarbonate in composition with low calculated total dissolved solids and relatively low specific conductance.

The second group of springs is located less than 3 miles southwest of Carlin on a slope west of the river in Section 5, T32N, R52E (SESW) (Figure 2-2). Geochemical information is not available for these springs, but discharge of fluids has been estimated at 400 GPM and temperature is reported as "warm." The temperature recorded by the writer during a site visit is 95°F (35°C). The water now issues from a culvert and the actual source of the springs has been covered over. It is not known whether these springs are part of the same geothermal system as those located near the Humboldt River.

2.1.2 Springs NW of Carlin, near Dry Susie Wash

The third group of springs is located just under 5 miles northeast of the town of Carlin near the Dry Susie Wash, in Section 8, T33N, R53E (NW¼) (Figure 2-3). The springs are called Hot Sulfur Springs in literature (Garside & Schilling, 1979). The seeps and springs are aligned in a N62W trend over a distance of approximately 1,800 ft (~ 550 m). Although the springs are indicated as Hot Springs on the 1967 Huntsman Quadrangle, an on-site inspection revealed only cold springs,

Figure 2-1 *Hot Springs Near Carlin Views Looking South-Southwest
Adjacent to State Highway 20 near Humboldt River Bridge*

Figure 2-1 Continued

Table 2-1 Geochemistry of Fluids from Springs near Carlin

	Carlin Springs SWSWSE Sec 33 T33N R52E	Dry Susie Wash Springs NW¼ Sec 8 T33N R53E
Temp (°C)	79.0	64.0
Flow (GPM)	300.0	15.0
SiO ₂ (ppm)	70.0	52.0
Ca	60.0	15.4
Mg	15.0	5.9
Na	45.0	231.0
K	16.0	26.5
HCO	335.0	690.0
SO ₄	52.0	25.0
Cl-	12.0	10.0
TDS (calculated)	545.0	1,055.0
SC (μmhos/cm)	625.0	1,130.0
pH	7.6	6.9
Geothermometers:		
SiO ₂ (°C) (quartz)	118.0	102.0 (suspect, see text)
Na-K-Ca (°C)	81.0	195.0 (suspect, see text)
Na/K (°C)	—	185.0 (suspect, see text)
SiO ₂ °C (chalcedony)	90.0*	—

* From Muffler and Others, 1978

Figure 2-2 Warm Spring Emerging from Culvert in Section 5

Figure 2-3 *View of Springs and Seeps Near Dry Susie Wash, Looking Southeast, Section 8*

most of them partially frozen. In August, 1978, a team from the University of Nevada Bureau of Mines and Geology (NBMG) sampled the springs at the extreme northwest end of the site and found them to be 147°F (64°C) (Trexler and others, 1979). As of November, 1980, these springs are no longer hot. The hot water recharge to this system apparently has been interrupted, possibly due to self-sealing along fractures. Geochemical data from the NBMG water sample analysis are shown in Table 2-1. Due to the high probability of pollution from cattle, the geochemistry is questionable for this system. The high sodium content is probably due both to interaction with sodium-rich subsurface rocks and cattle salt licks which were readily available in the vicinity of the springs.

2.1.3 Geothermometry

Geochemical thermometry is frequently used to evaluate the potential of a resource when little other than composition of the geothermal fluids is known. The following assumptions are made to consider the geochemical thermometry valid:

- a. Temperature-dependent reactions at depth control the concentration of the constituents used in the geothermometer.
- b. The reservoir contains an adequate supply of the reactants.
- c. Water-rock equilibrium is established in the reservoir.
- d. The constituents used in the geothermometer do not re-equilibrate with the confining rock as the water migrates to the surface.
- e. Mixing of thermal and nonthermal groundwater does not occur.

As more becomes known about a resource as a result of actual drilling, it is likely that all of these assumptions may not be valid and the resource temperature estimates may be disappointing. However, because the geothermometry is based on reasonable scientific principals and assumptions, they provide at least theoretical implications of the potential for further investigation or exploration.

Calculated silica, Na-K-Ca and Na/K temperatures for the Carlin resource are presented in Table 2-1 and are discussed here. The Na-K-Ca geothermometer for the Carlin Springs indicates an equilibrium temperature of 178°F (81°C), very close to the observed near-surface temperature of 174°F (79°C). The chalcedony geothermometer temperature is compatible at 194°F (90°C). Silica geothermometers are sensitive to dilution by groundwater introduced after water-rock interaction in the reservoir zone and their data are often suspect.

A calculation of the Na/K geothermometer resulted in an anomalously high reservoir temperature, well over 392°F (200°C). Generally the Na/K thermometry is only applicable where actual reservoir temperatures are less than 212°F (100°C).

The Na-K-Ca thermometry calculation is dependent upon the ratios of Na to K and Ca to Na, so fluids passing through sodium-rich sediments (such as evaporites) will give an anomalously high reservoir equilibrium temperature, whereas fluids passing through limestone rocks may be higher in calcium and the geothermometry temperature will be lower than the actual reservoir equilibrium temperature. Thus, calculated temperatures must be evaluated in light of the geologic

formations the fluids pass through on their upward migration path. The Carlin area is underlain by limestone formations, silty limestones, plus sandstones and shales intercalated with limestone beds. Therefore, one might expect the calculated Na-K-Ca temperature in the Carlin Springs area to be slightly lower than the actual equilibrium temperature. The low chloride concentrations (12 ppm) in the fluids are typical of groundwater chloride concentrations and are an indication that this is probably not a high temperature ($>150^{\circ}\text{C}$) resource where concentrations of chloride may be as high as 200 ppm. A linear trend between the measured spring temperatures and chloride concentration can provide insight as to whether groundwater has mixed with the geothermal fluids (Brook and others, pg. 22).

The geothermometry for the Dry Susie Wash springs is not considered to be accurate due to the questionably high sodium content in the water. The silica geothermometer was calculated to be 216°F (102°C), also higher than expected. There are beds of silica-rich diatomaceous earth in this area, so the silica constituent in the water may be anomalously high. Because the springs near Dry Susie Wash were found to be cold, they will no longer be considered for development in this study.

2.2 Geology of the Carlin Area

The springs in Section 33, T33N, R52E are located in stream-deposited alluvial fill of undetermined thickness, possibly underlain by Tertiary volcanics or volcanic sediments.

The dominating rock types exposed in the area of the geothermal occurrences are Tertiary silicic volcanics and volcanic sediments (Figure 2-4). Locally Tertiary andesite flows are present, particularly near the Springs in Section 8 near the Dry Susie Wash northeast of Carlin. Quaternary alluvium fills the washes and Humboldt River drainage.

The springs in Section 5 occur in the Humboldt Formation (restricted), an upper Miocene sequence of vitric ash and tuffaceous rocks of fluvial and lacustrine origin. The beds are composed of ash, tuff, siltstone, claystone and locally, intercalations of thin limestone beds (Smith and Ketner, 1976). The Humboldt Formation (restricted) overlies Paleozoic sediments which are dominated by limestone, calcareous siltstone, chert, cherty limestone and non-calcareous siltstone beds, all of marine origin. Tertiary volcanics, the Palisade Canyon Rhyolites, are exposed adjacent to the warm springs site.

Figure 2-5 shows the generalized structural features of the vicinity near Carlin. It is apparent from the map that subsurface structure of the immediate Carlin vicinity is not well defined at this time. The Carlin Pinyon Range south of Carlin has several major thrust faults and normal faults. Local faults associated with the hot springs have not been mapped, but from study of aerial photos, normal faults bounding the river can be inferred. The Carlin springs occur along an extrapolated NNE trending line which appears to form the eastern boundary of a graben structure through which the Humboldt River flows southward. It is also possible this prospect occurs along the intersection of a NNE trending fault and a regional fault trending N40E. There were no surface manifestations of faulting observed in the area of the springs in Section 33 near the river when the writer visited the site. The warm springs in Section 5 appear to be associated with a normal fault which forms the western boundary of the graben structure.

Figure 2-4 Geologic Map of Carlin Vicinity (Smith, 1976-56)

EXPLANATION

TERTIARY STRUCTURES

---+--- Anticline - Dotted where concealed

---+--- Syncline

LATE LATE JURASSIC OR EARLY CRETACEOUS STRUCTURES

Some of the folds may have been formed during Middle Pennsylvanian time and then folded again during Mesozoic time

---+--- Anticline - Dotted where concealed

---+--- Overturned anticline

---+--- Syncline - Dotted where concealed

---+--- Overturned syncline

---+--- Thrust fault - Dotted where concealed. Sawteeth on upper plate. Shaded areas include all exposed upper plate rocks

LATE MIDDLE TO EARLY LATE PENNSYLVANIAN STRUCTURES

---+--- Anticline

---+--- Syncline

---+--- Thrust fault - Dotted where concealed. Sawteeth on upper plate

LATE LATE DEVONIAN OR EARLY EARLY MISSISSIPPIAN STRUCTURES

---+--- Windows of lower plate rocks in Roberts Mountains thrust fault

---+--- Thrust fault - In upper plate of and assumed to be same age as Roberts Mountains thrust. Sawteeth on upper plate

NO AGE INDICATED

---+--- Normal fault - Dotted where concealed. D, downthrown side. Only a very few of the normal faults in the area are shown

..... Concealed normal fault - D, downthrown side. Plotted strictly on basis of geophysical data from Mabey (1964)

---> Stream - Arrow indicates direction of flow

Figure 2-5 Structural Features of the Northern Carlin, Pinion Range, From Smith and Ketner, 1977

Although the structural features in the vicinity of the resources are not well defined, it is assumed that the faults in the area are acting as conduits for hot water rising to the surface from the depths. A widely observed model in Nevada Geothermal Systems indicates that meteoric water (precipitation) enters faults in near-by ranges, migrates downward along the faults to great depths where it becomes heated. As the water becomes hotter, it also becomes lighter and starts to rise along fractures to the surface or near the surface. If the water temperature becomes high enough, it will interact with the confining rocks and absorb minerals, altering the chemical composition. The degree of change depends on how high the water temperature is and how long it is in residence at depth.

2.2.1 Geological History - A Brief Summary

The orogenic events that significantly affected the area include the Robert's Mountain Thrust, a major belt of sediments that was thrust eastward some 90 miles (145 km) over existing coeval shelf sediments during the Antler orogeny. The Carlin area lies just west of the leading edge of this fault (Figure 2-6).

Marine deposition in the region ceased when a regional uplift took place, probably in the Triassic time. The uplift was followed by emplacement of a thick series of nonmarine volcanic and volcanoclastic rocks in the region, now exposed in the Cortez Mountains south of Carlin.

The highlands created by the uplift and volcanism became the source of sediments for basins from the Cretaceous through early Tertiary periods. A period of renewed volcanism in the late Tertiary resulted in thick beds of ash flow tuffs and volcanics. Silicic intrusive stocks and dikes intruded Paleozoic sediments locally during the Oligocene period. Mining districts are associated with the emplacement of these stocks. The block faulting that formed the present basin and range topographic configuration occurred during the Miocene period.

2.2.2 Regional Aeromagnetic and Gravity Data

The aeromagnetic contour map (Figure 2-7) shows a north-south trending magnetic high located just west of Carlin centered over the southern end of the Tuscarora Range. The Carlin area lies on the eastern border of the anomaly. This aeromagnetic high is attributed to a buried shallow igneous body of considerable extent.

Existing gravity data (Figure 2-8) indicate that post-Paleozoic fill in the study area basins is much less than the total thickness of sedimentary units of the region (Smith and Ketner, 1976). The thickness of various exposures of single units in the area varies widely. Gravity interpretation conclusions imply that many episodes of deposition and erosion followed uplift.

2.2.3 Mineral Resources

Paleozoic and post-Paleozoic host rocks have been mineralized by intrusion of Oligocene igneous stocks and dikes. Most of the mineral resources occur in post-Paleozoic rocks. Metallic minerals mined in the region include gold, silver, lead and copper. However, the source of metallic mineral production generally attributed to the Carlin Mining District actually came from mines in the

Figure 2-6 *Early and middle Paleozoic tectonic setting showing distribution of autochthonous or paraautochthonous carbonate and transitional assemblages, allochthonous siliceous and volcanic assemblage, and leading edge of Roberts Mountains thrust*
From Stewart, 1980

Figure 2-7 Aeromagnetic Map of Carlin Vicinity (after Zeitz, Gilbert and Kirby, 1978)

Figure 2-8 Bouguer Anomaly Map of Northern Nevada, Showing Location of Study area.
From Hose and Taylor, 1974

Lynn Mining District, Eureka County (Tuscarora Range) (Smith, 1976). The Carlin Gold Mine, located 18 miles northwest of Carlin in the Lynn District and a principal economic contributor to the town of Carlin, was discovered in 1962. The ore bodies are contained in altered silty limestone beds of the Silurian Robert's Mountain Formation. Some 3 million tons of overburden were stripped from the site preparatory to mining in 1965 (Roberts, Montgomery and Lehner, 1967). Uranium prospecting (carnotite) has been conducted near Carlin in the vicinity of T32N, R52E (Deehead area, in a Devonian silicified breccia zone) and T32N, R53E (Black Kettle area, in Devonian siltstone), but no production resulted.

The Eisman Chemical Company mines barite, contributing significantly to the economy of the Carlin area. The barite mine is located in the northern Tuscarora Mountains north of Beaver Creek. The mill is 10 miles from Carlin in the Maggie Creek area.

Coal was discovered 2.5 miles east of Carlin in 1859 and was mined by the Humboldt Coal Company through 1874. Operations were suspended due to large volumes of water encountered in the shafts and adits (Smith, 1976). Another non-metallic mineral of commercial value in the immediate Carlin area is diatomite (in the Humboldt formation) which was mined 1.5 miles north of Vivian Siding (T33N, R52E, T33N, R53E) for over 30 years through 1952 (Smith, 1976).

Exploratory oil and gas wells drilled south of Carlin in Pine Valley and northeast of Carlin near Elko were unsuccessful dry holes. Oil shales of relatively high assay occur in the Elko Formation south of Carlin. The type section for this formation is 2,075 ft thick, located south of Carlin in T31N, R53E, between Sections 10 and 15. The oil shale beds are thin, so despite the high oil content, the deposit is not considered economically producible at the present time.

2.3 Hydrology

Depth to water in the Carlin vicinity is 10 ft or less (Eakin and Lamke). Table 2-2 summarizes the generalized hydrologic budget for the Elko hydrologic subarea as defined by Eakin and Lamke (1966). Precipitation is calculated directly, multiplying the area of the zone by the average precipitation. Inflow from upstream and outflow are measured. Water yield figures are computed and evapotranspiration loss figures are from direct calculations by Eakin and Lamke (1966). The presence of springs throughout the Elko subarea suggest that the Humboldt River flood plain in this region may be one of rising groundwater.

2.4 Reservoir Estimates

The volume and potential of these prospects must be estimated at this time using calculated figures and assumptions. Lacking information on subsurface structural control, it is difficult to postulate whether the two systems near Carlin are structurally connected or are separate systems. As mentioned earlier, there are no geochemical data for the springs in Section 5 (T32N, R52E), so a valid geochemical comparison cannot be made.

2.4.1 Reservoir Temperatures

The mean reservoir temperature of 96°C and standard deviation of $\pm 8^\circ\text{C}$ in Table 2-3 is simply the arithmetic mean of the three temperature estimates and their statistical deviation. The significance of the mean reservoir temperature is to provide an estimate of the most likely temperature one might expect, essentially based on geochemical parameters.

Table 2-2 Hydrologic Budget of Elko Subarea

	<u>Acre-feet/year</u>	
Precipitation		
Mountains	85,000	
Valley floor	160,000	
Total	245,000	
Inflow from Upstream	248,000	
Water Yield from Mountains		
Surface	5,000	
Groundwater	28,000	
Total	33,000	
Total Precipitation and Inflow to Area		526,000
Evapotranspiration		
From Mountains	67,000	
From Valley Uplands	137,200	
From Valley Lowlands		
Precipitation Loss	22,700	
Surface Water Loss	17,000	
Groundwater Loss	13,000	
Total	52,700	
Total Loss via Evapotranspiration		256,900
Outflow		
Surface Water	251,000	
Groundwater	Trace	
Total Loss via Outflow		251,000

From Eakin and Lamke, 1966

2.4.2 Reservoir Volume

The mean reservoir volume (with standard deviation) of 3.3 km³ (0.79 mi³) was estimated for the spring system based on standard representative areas for comparable systems (Brook and others, 1978). These estimates will be updated as geological, geophysical and drilling data become available, but they form a basis for evaluation of the prospect at this time. Table 2-4 tabulates the estimates of the reservoir temperature and volume potential for Carlin Hot Springs.

2.4.3 Reservoir Thermal Energy

The equation used for calculated mean reservoir thermal energy (in Joules) is:

$$q_R = \rho_c V_r (t - t_{ref})$$

where q_R is the reservoir thermal energy, ρ_c is the volumetric specific heat of rock and water (2.7×10^3 J/km³/°C), V_r is reservoir volume, t = reservoir temperature estimate and $t_{ref} = 15^\circ\text{C}$ (after Brook and others, 1978). This calculation is made for each temperature estimate and the means and standard deviations are calculated. The calculations for Carlin Hot Springs were prepared by Brook and others (1978) and verified for this report. The energy equivalent for the given thermal energy of 1.11×10^{18} J is 1.05×10^6 MMCF of natural gas and 1.72×10^8 barrels (bbl) of oil, or 1.05×10^{15} BTU's.

2.4.4 Wellhead Thermal Energy

All of the energy available in the reservoir will not be available at the wellhead because there are heat losses in the wellbore. Therefore, wellhead thermal energy is also estimated. The equation for wellhead thermal energy calculations (in Joules) is as follows (Brook and others, 1978):

$$q_{WH} = R_g q_R$$

where R_g , the geothermal recovery factor, is assumed to be 0.25, assuming that only 50 percent of the thermal energy is recovered in the process of recharge and discharge in an ideal hot water reservoir system. This 50 percent is further reduced one-half to account for non-ideal behavior in actual resources. Friction loss in the wellbore is not included since it is considered to be very small in comparison to the large uncertainties in the determination of the value for R_g . The calculated wellhead thermal energy is 1.83×10^{17} J or the equivalent of 1.74×10^{14} BTU's, 1.74×10^5 MMCF natural gas, or 2.86×10^7 bbl oil.

2.4.5 Extractable Heat

The non-electric extractable heat is calculated, but the electrical energy is not because the prospect's geothermometry implies reservoir temperatures are probably less than 150°C . Direct application extractable heat is equivalent to 4.17×10^{12} BTU's, or 4.17×10^4 MMCF natural gas, or 6.85×10^6 bbl oil.

Table 2-3 Estimates of Reservoir Temperature, Volume and Energy Potential for Carlin Hot Springs

Est. of Reservoir Temp. (From Table 2-1) (°C)	Na-K-Ca	81.000
	SiO ₂ (chalcedony)	90.000
	SiO ₂ (qtz)	118.000
Mean Reservoir Temperature and Standard Deviation (°C)		96 ± 8
Mean Reservoir Volume and Standard Deviation (km ³)		3.3 ± 0.9*
Mean Reservoir Thermal Energy (q _r) and Standard Deviation (10 ¹⁸ J)		1.11 ± 0.32*
Wellhead Thermal (q _{WH}) Energy (10 ¹⁸ J)		0.183*
Extractable heat (10 ¹⁸ J) (R _g) (as non-electric beneficial heat)		0.044
Extractable heat (10 ¹² BTU)		41.738

* From Brook and others, 1978

The calculation for extractable non-electric heat in Joules was made using the following (after Brook and others, 1978) equation:

$$EH(J) = q_{WH} \mu_B$$

where $\mu_B = 0.24$, representing the fraction of thermal energy obtained when 100°C water temperature drops by 20°C, and q_{WH} is wellhead thermal energy.

The extractable heat potential appears to be high for this resource. However, these are preliminary estimates. Geothermometry is not conclusive evidence of the reservoir temperature and all calculations for extractable heat and reservoir temperature are based on the geochemical thermometry. As additional reservoir data become available, more accurate estimates can be made.

2.5 Exploration Program

The absence of subsurface data or detailed geophysical and geologic data prevents adequate appraisal of the potential of the geothermal resources in the study area. A relatively complete exploration program must be conducted before resource utilization can be realized. The exploration plan which follows is intended to yield the required data for resource evaluation and utilization. This plan is only a recommendation for strategy. The entire plan as presented is not necessarily required to develop the prospect for small developers. The location of the exploration area is shown by Figure 2-9.

Exploration program strategy is to determine structural relationships between known surface geothermal manifestations in the Carlin vicinity, delineate the geothermal reservoir limits and obtain quantitative data from well flow tests to support utilization requirements.

2.5.1 Structural Relationships

To better understand the structural relationships between the previously discussed springs, both geological and geophysical techniques should be employed as follows:

- Phase 1. Geologic Mapping & Geochemical Sampling

Detailed geologic mapping of the sites, some 160 acres each, should include a description of surface alteration. Water sampling of unsampled springs will be accomplished at the same time as mapping. The effort should be supported by a review of Landsat photos, both low angle sun and snow cover exposures (available through the BLM).

Mapping Costs

One senior geologist, including travel and subsistence, vehicle, map preparation and drafting, photo review; 2 field days, 3 office days: \$1,600.

Figure 2-9 Exploration Target - Carlin Hot Springs. (AMS 15 minute Topographic Base Map)

- **Phase 2. Gravity Survey**

A gravity survey is needed to determine local gravity configurations. Regional data are available, and employing both sets of data, combined with the density contrast of the sediments and bedrock, an estimate of alluvium thickness can be calculated. This is particularly important for the springs located near the Humboldt River.

The gravity survey should be conducted over an 8 mile long by 2 mile wide area to incorporate the greater Carlin area (Figure 2-10).

Gravity Survey Costs

8 mile x 2 mile area with ½-mile station spacings, totaling 80 stations at \$36/station (est.) including data reduction, modeling, interpretation: \$3,000.

- **Phase 3. Seismic Survey**

Seismic refraction surveys are sometimes useful in geothermal exploration programs to provide structural information (fault zones) and reasonable definition of the depth to basement rocks. Seismic reflection may not be useful here because volcanic sequences may lie under the valley fill and poor results are obtained under these conditions.

The refraction survey method is intended to provide detailed information on the upper 600 meters of geologic section. The seismic data are correlated with information from the gravity surveys and geologic mapping to assist in delineation of fault zones, alteration zones and depths to basement. Having completed the seismic survey, mapping and gravity data should be correlated with results to site temperature/lithology holes.

Seismic Refraction Costs

Three line miles including mobilization, data reduction and report preparation: \$7,000.

2.5.2 Reservoir Delineation

Direct exploration methods including shallow temperature gradient holes are necessary to obtain detailed information regarding reservoir temperature, lithology and areal extent leading to the siting of exploratory/production well(s). Optional geochemical and geophysical techniques may be employed if results from gradient holes are insufficient to site the exploratory/production well(s).

- **Phase 4. Shallow Temperature Gradient Holes**

The shallow holes will be sited based on geologic mapping, gravity and seismic data evaluation. Six 150 to 300 ft (50 - 100m) deep holes should be drilled to provide temperature, lithology and geochemical data. The data that can be acquired from these holes are as follows:

Figure 2-10 Gravity Survey Area - Carlin Vicinity, BLM Public Lands Guide, Base Map

- **Lithology:** A lithologic log is kept for each hole during drilling. Cuttings are sampled every 10 feet and composited over 100 ft intervals for chemical analysis.
- **Temperature:** Temperature is monitored in the hole both during drilling and after the hole attains thermal equilibrium. Temperature gradient measurements are plotted and contoured to assist in siting production wells.
- **Phase 5. Geochemical Survey**

A geochemical analysis will be performed on 2 composited samples per hole for 12 elements of importance to geothermal systems. The composited samples will be analyzed, plotted and evaluated. With proper interpretation, the geochemical survey may provide another site selection tool for production wells.

Geochemical analysis is a relatively new tool to assist in determining the depth to a producing zone. Based on geochemical relationships, siting can be made in areas where the producing zone is closest to the surface. Thus far, other more costly exploration techniques have failed to successfully accomplish this cost-saving factor.

Shallow Drill Hole Costs

- Average cost estimate for drilling is \$14.00/ft. Six 300-ft deep 4½ in. holes: \$25,200.
- Logging (temperature and water), drilling/logging supervision, and data reduction/drafting/sample handling/supplies: \$10,200.

Total shallow holes cost: \$35,400.

Geochemical Survey Costs

Analysis of 2 composited samples per hole for 12 elements (12 samples), including data reduction/interpretation: \$1,500.

A decision should be made after Phase 4 and 5 as to whether exploratory/production wells should be drilled. Sufficient data should be available, but if ambiguity exists, a mercury-arsenic soil survey and/or dipole-dipole resistivity survey could be employed to enhance existing data.

- **Phase 5A. Mercury-Arsenic Soil Surveys (Optional).**

The survey would be conducted on a 1 mile grid with spacing of ~ 150 ft in the Section 5 resource area, only if all previously discussed methods fail to provide adequate data for siting a well. Surface expressions (faults, springs, seeps, wells, alteration patterns) assist in determination of the grid pattern. Anomalous mercury highs are signatures of a geothermal system. Mercury is known to partition strongly into the vapor phase flashed from hot geothermal waters. The mercury-bearing vapor migrates to the surface along permeable zones that either connect with thermal-water aquifers or are themselves thermal-water aquifers. As a result, the mercury traces in soils may delineate sub-surface thermal-water structural features.

Arsenic can be analyzed for only a few dollars per sample more and provides valuable interpretation data. Arsenic comes to the surface with thermal waters and therefore is a clear indication of a hot water system as the source of alteration, as opposed to only fumarolic activity. There will be no arsenic in the sample if thermal waters did not reach the surface. The pattern of anomalies is not as coherent as mercury, but the combination provides a relatively comprehensive interpretation tool.

The Mercury-Arsenic Soil survey is not recommended for the Section 33 resource because it is located on a flood plain and select chemical traces have probably been covered and/or washed away. Stream deposited mineralization is also conceivable in this flood plain. In addition, anomalously high mercury readings are associated with roads and highways and the springs are adjacent to a state highway. Data from this survey must be interpreted very carefully as there are several pitfalls which could lead to faulty conclusions. With proper interpretation, a rough approximation of the structural trend controlling fluid flow may be discernible.

Costs for Survey

- \$7.00/sample for Hg-As elements lab analysis, estimated 50 samples on a 1 mile grid, including 4 wheel-drive vehicle, junior field geologist, travel and subsistence, plus consultant for data interpretation and sample collection methodology (1 day at \$400): \$2,080.
- Phase 5B. Dipole-Dipole Resistivity (Optional).

This exploration technique is not recommended for the initial exploration program because the basin and range province alluvial valleys are frequently quite conductive near the surface. A valley may contain up to 2,000 ft or more of alluvial fill, beyond the penetration range of Vertical Electrical Sounding (VES). Because of the high conductivity in the fill, the depth sensitivity is no better than two times the electrode separation; that is, only 600 m deep for the 300 m spacing.

However, more structural control may be achieved to supplement existing data with a resistivity survey, particularly in the zone near Section 5 springs. It is conceivable that the resistivity survey may produce poor results for the springs near the Humboldt River due to the probability that thick clayey, conductive flood plain sediments will impede signal returns, even at close spacings, and mask the actual geothermal structural trends.

Costs for Dipole-Dipole VES Survey

Two 3,000 ft lines (1 km) for Section 5 at \$485/line (est.): \$970 to \$1,000.

2.5.3 Phase 6, Exploratory/Production Well(s)

The drill site selection will be based on evaluation and correlation of all surveys performed during the exploratory phases. A total depth of 1,500 ft should be the target for this drill hole.

It is likely that the 1,500 ft depth may not be necessary. Known hydrology and evidence from water wells recently drilled in the vicinity indicate the probability of a shallow resource. Should a significant production zone be encountered prior to the 1,500 ft target, drilling should be suspended and the well should be prepared for testing. Backup sites should be selected at the prospect in the event difficulties prevent drilling or completing the primary drilling target.

Testing of the exploratory well will be conducted following completion. Standard testing procedures will be employed. A decision will be made to site another exploratory/production well if the well is non-productive. The well will be completed for production if successful. Costs for a second well are not included because success is assumed.

The well is designed for setting a pump at 300 ft, capable of producing 300 to 350 GPM. This will require setting the casing to at least 350 ft. Either a shaft driven pump (motor at surface, impellers downhole) or submersible pump (motor and impellers downhole) can be utilized. Pump horsepower requirements assume a pumping fluid level of 100 ft.

Estimated Current Costs for Exploration/Production Well

One exploratory/production well, 1,500 ft deep, including logging suite, at \$60/ft. Hole is 9-7/8 in. to 350 ft, cased with 7 in. casing, and 6-1/4 in. hole to 1,500 ft, if necessary: \$90,000.

Plus materials and completion supplies: \$5,500.

Total Cost: \$95,500.

Plus testing one 1,500 ft hole (est.): \$10,000.

Total drilling, logging, testing, completion: \$105,500.

Pump costs are discussed in Section 3.1.3, and are not included in completion costs.

Table 2-4 summarizes overall costs for the exploration plan, Table 2-5 offers the alternate plan, and Figure 2-11 graphically displays the time frame by phase, including permitting and decision points. It should be noted that the time frame allows for the drilling of two exploration wells even though success of the first one is assumed. Only 2½ months will be required if the first well is a successful producer.

Table 2-4 Cost Summary Primary Exploration Plan

<u>Technique</u>	<u>Cost</u>
<u>Phase 1</u>	
Detailed geologic mapping	\$ 1,600
<u>Phase 2</u>	
Gravity survey - 80 stations, ½ mile spacing over 8 mi x 2 mi target zone at \$36/station including data reduction	3,000
<u>Phase 3</u>	
Seismic refraction survey - 3 one-mile lines	7,000
<u>Phase 4</u>	
Six shallow 4½ in. diameter, 300 ft deep temperature gradient/lithology holes at \$14/ft including logging, supervision, data reduction, supplies	25,200
<u>Phase 5</u>	
Geochemical survey from drill hole cuttings	
Twelve elements from 2 composited samples per hole, or a total of 12 samples, including data reduction and interpretation	1,500
Subtotal for Primary Exploration Plan	<u>\$ 38,300</u>
<u>Phase 6</u>	
One 1,500 ft exploration/production well at \$60/ft, including testing	\$105,500
Total Primary Plan	<u><u>\$143,800</u></u>

Table 2-5 Cost Summary, Alternate Exploration Programs

	<u>Alternate Plan Cost</u>	<u>Total Costs</u>
Balance Forward from Primary Plan, Table 2-5		<u>\$143,800</u>
<u>Technique</u>		
<u>Phase 5A - Carlin Alternate Plan - Supplementary Data only if necessary.</u>		
Mercury-arsenic Survey on 1-mile grid at \$7/sample, Section 5: \$2,080		
Subtotal if Phase 5A is necessary	<u>\$145,880</u>	
<u>Phase 5B - Supplementary Resistivity Data if necessary.</u>		
Two dipole-dipole resistivity lines 1 km long for Section 5 prospect only at \$485/1 km line including data reduction: \$1,000		
Total if 5B is needed	<u>\$144,800</u>	
Total if 5A and 5B are both necessary (Maximum Cost for all techniques)		<u>\$146,800</u>

Carlin (Sec. 33 & 5)

Month

→ Alternate Plan
 ▲ Decision Point, Milestones
 ▲ Decision for Production

Figure 2-11 Time Element for Geothermal Exploration Plan

3.0 Development Plan for Carlin

3.1 Review of Appropriate Applications

Several applications may be possible for the Carlin area. Those considered in this study are:

- Ethanol Production
- Greenhousing
- Animal Husbandry
- Spas
- Prawn Ponds
- Space Heating

Ethanol production is not recommended at the present time because current technology requires a minimum of 250-300°F (120 - 149°C) for plant processes such as saccharification, distillation and stillage dehydration. If the resource is found to encounter temperatures of this magnitude at depth, then serious consideration can be given to an ethanol plant.

Greenhousing is a possibility for a cascaded application, using residual heat from a primary application such as district space heating. The capital costs for greenhousing vary widely, depending on the size of the structures, the temperature of the hot water and the materials used for construction of the facility. Total flow requirements depend on the extent of the complex, generally ranging from 700-800 gallons per minute for a ½-acre sized greenhouse. The minimum temperature requirement is 140°F (60°C). Considering the anticipated temperature from the Carlin resource, an extensive greenhouse operation would be desirable if the resource is to be utilized at an optimum level. However, small scale greenhouses from relatively shallow wells, providing that the well encounters at least 150°F, would be feasible for property owners on land with geothermal energy potential.

Animal husbandry, spas and prawn ponds are all feasible, but would be under-utilizing the resource at a primary-use level. Ranchers may wish to develop wells on their own property for animal husbandry or heating facilities.

Figure 3-1 defines the temperature requirements for selected non-electric applications. The anticipated Carlin resource temperature range is indicated. All applications within that range, up to 176°F (80°C), are appropriate and technologically feasible at the present time.

For the purposes of this study, space heating is considered to be the most desirable application for several reasons. The distance from the hot springs to the nearest cluster of 50-60 existing homes is only 1.4 mi (2.25 km). The fluids have low total dissolved solids and a favorable temperature for space heating on a district basis. In addition, the hot water heat will be able to replace existing fossil fuel usage, namely natural gas. Therefore, a model has been developed as an example for maximum utilization of the resource for a primary application. Cascaded uses can be designed into the system when more definite data are available about the resource.

Figure 3-1 *Approximate Geothermal Fluid Temperatures for Selected Non-Electric Applications. Source: Geothermal Energy Prospects for the Next 50 Years, EPRI ER-611-SR, Special Report, February, 1978*

3.1.1 Direct Space Heating Potential - A Model

Basically, the homes are double-wide mobile homes on permanent foundations. The average size of the double wides and other homes in the vicinity is 1,400 sq. ft.

Since the reservoir characteristics that are vital to design of a detailed site specific engineering design are not known, a model for space heating will be described. Space heating is considered to be the most appropriate direct application for this resource.

The principal heat source for homes in the area is natural gas through Southwest Gas Corporation. The November, 1980, gas price to the consumer in Carlin is \$0.493/therm (T). One therm is 100,000 BTU's and is equal to 1 CCF. Energy efficient families in 1,400 sq. ft. homes averaged \$50.00/month heating bills in the winter months of 1979, largely due to keeping the indoor temperature at 65°F. Less energy conscious homeowners in approximately the same space had bills up to \$85.00/month, maintaining an indoor temperature in the lower 70°F range.

There are presently only 8 electrically heated homes in the City of Carlin. Carlin generated its own electricity until they sold out to Wells Rural Electric Cooperative in 1978. The price to consumers is \$0.06/kwh. Wells Rural electricity is basically hydroelectric power from the Bonneville Project in Idaho.

3.1.2 Space Heating Requirements

A model is presented for heating 1,400 sq. ft. homes, some of which have full basements. Roughly 60 homes per well could be heated based solely on what is known of the resource at this time. The heating requirements are listed in Figure 3-2. All equations employed are given in Appendix A.

The total annual energy requirements for 60 homes will be approximately 4.9×10^9 BTU/yr, assuming 8.5×10^7 BTU/yr per home. At the current gas price of 0.493/therm, the total annual heating bill per home is \$402/heating season, assuming a 7-month heating season and 8.15×10^7 BTU/yr heating load per home.

3.1.3 Preliminary Engineering

Several assumptions have been made in order to develop an engineering design model for a space heating project. The assumptions are listed in Figure 3-3. The distance to users is 1.4 miles (2.25 km) and the total calculated degree F days are 6,788 or 3,753 degree C days (Table 1-6).

The 300 GPM flow is the minimum requirement for the number of homes in the model. The literature indicates a 300 GPM natural flow from the springs. However, the model includes pumping the fluid, taking into consideration the possibility that the well may not flow spontaneously at the 300 GPM rate. If the well does flow spontaneously to the surface, a circulating pump at the surface will suffice. A total well depth of 1,500 ft. is assumed. However, based on hydrological data, it is likely that the actual producing zone will be encountered at a shallower depth,

Maximum Heat Load (HL_{max}) = 41,500 BTU/hr

where inside temperature is 70°F
and outside design temperature is -13°F

Annual Heat Load (HL_a) = 8.15×10^7 BTU/yr

Delivered Heat (H)
(includes 25 percent overdesign) = 51,875 BTU/hr

Fluid Flow Rate ($\dot{w}$) = 5.2 gpm/home or 7,488 gpd/home

Fluid Flow at Springs = 300 gpm or 432,000 gpd

Number of homes = 60

Annual Utilization Factor = 0.22

Equations and Calculations are listed in Appendix A.

Figure 3-2 Heating Requirements for Space Heating in Carlin

Number of homes	60
Flow (pumped)	300 gpm
Temperature at wellhead	170°F (77°C)
Well depth (maximum)	1,500 ft (450 m)
Producing Zone	500 ft (150 m)
Pumping fluid level	100 ft (30 m)
Downhole Pump Size	12.5 hp
Curculating Pump Size	20.0 hp
Life of geothermal resource	30 yrs
Delivery Pipe Size (ID)	6 in.
Downhole Pump Efficiency	85 percent
Inside design temperature	70°F (21°C)
Outside design temperature	-13°F (-25°C)

Figure 3-3 *Assumptions for Engineering Design Model for Space Heating*

possibly 200 to 500 ft, provided the hole is sited properly. A fluid pumping level of 100 ft is chosen based on water well drilling records of wells in the immediate vicinity where static water levels are 10 to 60 ft deep. Total horsepower for the downhole pump is 12.5 hp. The circulation pump requirement is a maximum of 20 hp for the system. Calculations for pump size determinations are given in Appendix B. Temperature at the wellhead is based on observed data. The assumed life of 30 years for the geothermal resource is not unrealistic. Heating districts exist which have operated from the same wells for over 30 years (Boise, Idaho, for example).

The supply line pipe size of 6 in. is the most appropriate diameter to handle the 300 GPM flow required. The model provides for an additional 50 psi at the end of the principal supply line for the distribution system to homes. Lines from the main supply line to homes will be 3/4 in. pipe. The sketch of the distribution layout in Figure 3-4 is an idealized model layout. The heating system is a fan-operated convector unit, where air is heated by being blown across coils containing circulating hot water (see Figure 3-5).

The cost of retrofitting will be approximately \$500 which is assumed to be absorbed by the homeowner. He is entitled to a 40 percent federal energy tax credit, an estimated \$200 deduction for retrofitting. A spent fluid disposal system is assumed to consist of a 3/4 in. line exiting the home, parallel to the supply line. Costs are not included, but 3/4 in. PVC pipe can be utilized at minimal cost. The main disposal line to the ponding area need not be insulated and will not sufficiently increase costs to alter the economic aspects of the design.

3.1.4 Costs for Space Heating Model

Costs for the model are summarized in Table 3-1 and all equations employed are given in Appendix C. The prices for pipes and equipment are current cost estimates in 1980 dollars. Items listed in Table 3-1 and any assumptions involved in cost determinations are described here.

Maintenance costs are assumed to be 3 percent of capital costs. This may be somewhat higher than actual costs for this particular system. Calculations for maintenance and operating expenses are made for two cases, the first being that both a downhole and circulating pump are necessary, and second, that only a circulating pump is required. In the latter case, annual maintenance costs are minimal.

The well costs of \$105,500 are taken from those determined in the exploration plan, assuming drilling to a total depth of 1,500 ft (450m) is necessary to define the best producing zone. Wellhead equipment is considered in the drilling and completion costs.

The cost estimate for the downhole pump is \$4,425, essentially \$350/hp plus \$50. The current price for circulating pumps is roughly \$100/hp, a total of \$2,000 for this model. The supply pipe, buried and insulated 6 in. pipe, is \$168,960, at \$16/ft over a total of 2 miles (including supply line within distributing area).

Two interest rates are used for capital financing, 10 percent and 13 percent. For purposes of this model, it is assumed that funding assistance is obtained through the DOE User-Coupled Drilling Program which funds up to 20 percent of the successful producing well.

Figure 3-4 Idealized Diagram for Heating District Layout

*Figure 3-5 Simplified Diagram of Forced Air Geothermal Space Heating.
From EG&G, Idaho*

Table 3-1 Capital Investment and Annualized Costs for Space Heating Model

	<u>Case 1</u>	<u>Case 2</u>
Well Costs	\$105,500	\$105,500
Downhole Pump	4,425	—
Circulating Pump	2,000	2,000
Supply Pipe	168,960	168,960
	<u>\$280,885</u>	<u>\$276,460</u>
Less DOE User Coupled Funding Assistance (20 percent of production well costs)	<u>-21,100</u>	<u>-21,100</u>
Total Capital Investment	259,785	255,360
Annual Capital Costs over 30 yrs:		
at 10 percent interest	27,558	27,088
at 13 percent interest	34,658	34,067
Maintenance at 3 percent Capital Costs	7,793/yr	—
Maintenance at 1 percent Capital Costs (est.)	—	2,550/yr
Operating Costs at \$0.06/kwh electricity - pumps (for 7 mo. heating season)	1,634	1,006

Note: Case I assumes a downhole pump is necessary to provide the required 300 GPM for the model. Case II assumes natural 300 GPM flow to the surface and only a circulating pump would be needed to pump water homes. Maintenance costs will be considerably lower in this case.

Royalties for leases are not included in the financial model due to the unique nature of leasing water rights. The negotiated royalties may be considerably less than the usual 10 to 12 percent. Tax incentives are not applied because it is not certain whether geothermal tax incentives described in Section 3.2.3 of this study will be applicable to this development. It depends on the approach taken in setting up the heating district, whether as a privately owned utility, a municipally owned utility, or cooperative utility owned and managed by the homeowners.

3.1.5 Present Value Comparison

Actual price projections for natural gas for the next 10 years are listed in Table 3-2, compared with the calculated cost/therm for geothermal energy over the same time period. A present worth comparison (Table 3-3) between geothermal and natural gas for a resource with an energy content of 5.6×10^{10} BTU/yr indicates that the economics of developing the Carlin resource are very favorable. The break-even point would be within 5½ years for Case 1 and just less than 5 years for Case 2.

The extractable energy estimate of 5.6×10^{10} BTU per year employed in this section is based on estimates published by EG&G Idaho Operations (1978) for a 300 gpm resource at 170°F (77°C) rather than the extractable energy estimate for the Carlin resource listed in Brook and others (1979). Their estimate of 4.17×10^{13} BTU/yr appears to be high.

3.1.6 Conventional Fuel Replacement Estimate for Proposed Model

The total amount of natural gas replaced during the heating season as a result of 60 homes converting to geothermal space heating for this model will be 5.0×10^3 MCF the first year, 5.0×10^4 MCF in 10 years, and 1.5×10^5 MCF total over the 30-year period. Calculated heat load requirements of 8.15×10^7 BTU per year were used to estimate the natural gas used per home.

3.1.7 Single Dwelling Economics

Based on the foregoing price estimates, (see Table 3-2), the consumer would pay less per heating season for geothermal heat compared to the natural gas heat:

	Case 1 at 10% Int.	Case 2	Case 1 at 13% Int.	Case 2
Geothermal cost/ heating season	\$246	\$203	\$292	\$250

If the total current natural gas cost per heating season is assumed to be \$402 (see Section 3.1.2), consumers will save on their heating bills in all cases, and payback for the estimated \$500 retrofitting costs will occur within 2 to 2½ heating seasons. If the homeowner takes advantage of the \$200 energy tax credit, payback could occur within 1 to 1½ heating seasons.

Table 3-2 Natural Gas Prices vs. Geothermal Prices

<u>Natural Gas⁽¹⁾</u>		<u>Geothermal (\$/Therm)⁽²⁾</u>			
<u>Year</u>	<u>\$/Therm-delivered</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 1</u>	<u>Case 2</u>
		<u>@ 10% Int.</u>		<u>@ 13% Int.</u>	
1980	0.493	0.301	0.249	0.358	0.306
1981	0.593	0.302	0.250	0.359	0.307
1982	0.600	0.303	0.250	0.361	0.307
1983	0.664	0.304	0.251	0.362	0.308
1984	0.732	0.305	0.252	0.363	0.309
1985	0.810	0.307	0.253	0.365	0.310
1986	0.892	0.308	0.254	0.366	0.311
1987	0.983	0.310	0.255	0.368	0.312
1988	1.082	0.312	0.256	0.370	0.313
1989	1.196	0.314	0.257	0.372	0.314
1990	1.324	0.316	0.259	0.374	0.315

(1) Actual price projections for natural gas in Nevada.

(2) Rate of escalation is 8 percent per year.

Note: Geothermal price is calculated using the following equation:

$$\$/\text{Therm} = \frac{\text{Maintenance} + \text{Pump Costs} + \text{Annual Capital}}{\text{Maximum heat available} \times \text{AN}}$$

where maximum recoverable heat for a 300 gpm well at 170°F is estimated to be 56×10^9 BTU/yr.

**Table 3-3 Net Present Value Comparison: Natural Gas vs. Geothermal Costs
for a 300 GPM 170°F Resource**

Year	Gas Therm/yr x \$/Therm	Net Present Value	Geothermal Costs Undiscounted		Net Present Value - Geothermal	
			Case 1	Case 2	Case 1	Case 2
0	\$ 0		\$-259,785	\$-255,360	\$-259,785	\$-255,360
1	-60,639	-55,126	-9,427	-3,556	-8,569	-3,232
2	-66,297	-54,791	-10,180	-3,840	-8,408	-3,172
3	-73,800	-55,424	-10,994	-4,147	-8,256	-3,115
4	-81,672	-55,781	-11,873	-4,479	-8,109	-3,059
5	-90,036	-55,912	-12,822	-4,837	-7,961	-3,004
6	-99,630	-56,191	-13,848	-5,223	-7,810	-2,946
7	-109,716	-56,289	-14,956	-5,641	-7,672	-2,893
8	-120,909	-65,290	-16,152	-6,092	-7,534	-2,845
9	-133,086	-66,543	-17,443	-6,579	-7,395	-2,789
10	-147,108	-68,111	-18,839	-7,105	-7,253	-2,743
Total		-589,458			-338,752	-285,158

Note: Maintenance and Power Costs are escalated at the rate of 8 percent per year. Annual costs are discounted at 10 percent using the Present Worth Method of Evaluation

3.2 Development Plan Financing

3.2.1 Financing of Exploration Program

The highest financial risk occurs drilling the exploration phase of development. However, there is some possibility of assistance for the drilling and testing phases of the exploration plan through the U.S. Department of Energy (DOE) User-Coupled Drilling Program. At the present time, a proposal must be submitted to DOE Idaho Operations Office when the announcement of requests for proposals is made. An offer can be made for cost sharing the drilling and testing phase of the exploration program. The DOE program absorbs a considerable portion of the risk for the drilling. The program will pay up to 90 percent for an unsuccessful well. For a successful well, DOE will absorb up to 20 percent of the drilling and testing costs, based on the degree of success. In the future, developers may apply for a loan under an amended form of the User Coupled Drilling Program with a percentage of the loan forgivable in accordance with the degree of success. More information may be obtained through the proper contact as listed in Appendix F.

Other forms of financing involve private developers and investors. These funds may be difficult to raise for Carlin since little is known of this resource. In addition, current interest rates curtail opportunities to raise private funds for geothermal development.

If serious interest in development of a local project is coincident with funding of the State Coupled Geothermal Resource Assessment efforts (Nevada Bureau of Mines and Geology), exploration assistance can be received through the Nevada Department of Energy. A valid request, if approved, would enable the state team to obtain DOE funds on an existing contract to complete a standard suite of exploration surveys to evaluate the potential of the resource, thus absorbing a considerable portion of the initial costs at the high risk stage. In the case of Carlin, the State Coupled Geothermal Resource Assessment Team has requested funds from USDOE to evaluate the resource. A decision will be forthcoming in April, 1981.

3.2.2 Financing a Facility

If the exploration efforts successfully define a viable resource, facility financing efforts can commence.

The alternatives for financing are:

- Private investors
- Municipal bond issues
- DOE Geothermal Loan Guaranty Program (GLGP)
- DOE Program Opportunity Notices (PON's)
- DOE Program Research & Development Announcements (PRDA's)
- DOE Geothermal Energy Technical Assistance Program
- DOE National Energy Conservation Policy Acts Grants
- USDA Farmers Home Administration Community Facility Loan
- HUD Community Development Block Grants
- HUD Comprehensive Planning Assistance Grants
- Small Business Administration Loans

Private investors may be sought by an individual or group of individuals who wish to develop part of the resource for commercial enterprises such as greenhouses, prawn ponds or spas. Municipal bonds are a possibility for a district space heating project or heating of public facilities. The U.S. Department of Energy (DOE) has many incentive and assistance programs (listed above) to encourage development of alternate energy resources. A brief narrative of these programs follows.

PRDA's provide an opportunity for prospective developers to propose site specific engineering and economic feasibility studies for direct applications of geothermal resources prior to selection of an exact location and actual design of a facility.

The National Energy Conservation Policy Act Grants encourage reduction of fossil fuel consumption in public facilities such as schools and township building by offering cost-shared grants to identify energy conservation measures, such as utilizing renewable energy resources (geothermal energy and solar energy, for example).

The U.S. Department of Agriculture (USDA) offers loans to municipalities in rural areas for development use. The funds may be used to acquire land or leases to construct or improve community facilities. The interest rate was 5 percent in 1980 with a maximum term of 40 years. Loans over \$2 million must be submitted to the National Farmers Home Administration (FMHA) for approval. If Carlin township considers using the geothermal resource for heating the school and public buildings, this opportunity may be of interest. Applications are made at the county FMHA office.

The U.S. Department of Housing and Urban Development (HUD) offers aid in the form of block grants to promote community developments. State and local government may also apply for comprehensive planning assistance grants to determine needs and goals for land use, housing and community facilities. This assistance may be appropriate for the planning stage of a municipal project.

The Small Business Administration (SBA) now offers an energy direct loan and loan guaranty program to encourage development of energy saving projects. A loan may be used to purchase land, buildings, machinery, equipment, furniture, fixtures, supplies, materials or can be used as working capital.

In addition, direct loans can be used for services such as engineering, architectural or other related consulting requirements.

A list of contacts for most of the discussed financing opportunities are included in Appendix F.

3.2.3 Taxes Affecting Exploration and Development

The Energy Act of 1978 incorporates tax incentives for geothermal energy development. The main areas of interest here are intangible drilling deductions, tax credits and depletion allowances.

Intangible drilling costs can be expensed, as is allowed for the oil and gas industry. The items which can be expensed or deducted include non-salvagable expenses such as wages, fuel, repairs, hauling and supplies incidental to drilling completion. The deduction is valid whether the well is dry or productive.

The depletion allowance is a fixed 22 percent of the gross geothermal production income which may be excluded from taxable income. The deducted amount cannot exceed 50 percent of net income.

A tax credit of 10 percent is in effect from October 1, 1978 to December 31, 1982. This is an additional 10 percent income tax deduction in excess of the normal 10 percent investment tax credit allowable for geothermal equipment. This combination of tax credits can substantially reduce the original investment for the well casing, pumps, valves, piping and heat exchangers.

Certain municipally-owned geothermal systems may not be eligible for some of the federal tax incentives. Private developers with minimal income from sources other than geothermal systems may not be able to take full advantage of these tax benefits.

When the cost of retrofitting is absorbed by the homeowner, he is entitled to a 40 percent energy tax credit deduction on his taxes up to a maximum credit of \$4,000. In this model, the \$500 cost estimated for retrofitting would result in a \$200 tax saving to the homeowner.

The State of Nevada, in an effort to encourage homeowner's conversion to geothermal energy, exempts the added value of domestic heating geothermal developments from local property taxes.

3.3 Time Frame and Sequence of Events Leading to Development

The time frame within which overall development could take place under normal conditions is outlined in Figure 3-6. A factor for unforeseen obstacles is built in to all estimates.

In this specific case, the property is located on private land with mineral rights being retained by the railroad. Geothermal is under the auspices of state water laws and the owners of surface and water rights must be approached for leases or outright acquisition of the property. Lease negotiations may be as lengthy as one year, so the estimate here is a maximum amount of time anticipated for the leasing process. If a spirit of cooperation exists, negotiations may be concluded well within one year.

Obtaining financing of the exploration effort should commence as soon as assurance has been received that leases will be approved. The time frame given assumes response to a request for proposals to the DOE User-Coupled Drilling Program. A loan application to the amended form of this program conceivably could take considerably less time, approximately 3 months.

The permit for production wells can be applied for with the State Division of Water Resources as soon as leases and financing are finalized. The specific drill site is not required on the permit, but the well must be located within a one square mile radius of the permit location. The exploration and testing time span is outlined in Section 2.6.

Figure 3-6 Developmental Time Frame

Since the resource is on private property and there are no city or county environmental requirements, the environmental assessment will be necessary only as the property owner, lending institutions or DOE require. A response to the DOE User-Coupled Program must include a preliminary environmental report, not a full-scale environmental impact statement.

The amount of time considered necessary for obtaining facility financing in Figure 3-6 is for a GLGP loan application, including concurrent negotiations with a participating bank or lending institution. The MPDS Permit mentioned in Item 7 is described in Section 3.4.4.

Drilling of production wells and facility construction can commence upon loan approval. However, engineering design can be undertaken during the period when finances are being finalized if funds are readily available. Construction and retrofitting can get under way during production well drilling. The total developmental time span will be approximately 3 years from project initiation. If private financing is obtained, some 6 to 8 months can be cut from the total time required.

3.4 Institutional and Regulatory Factors

All regulatory factors that might be encountered may not be adequately covered in this study because some aspects are not clearly defined. Additional regulations may be enacted prior to or during development of resources in Nevada.

3.4.1 Federal Laws — BLM Land

Because this resource is not located on federal land, federal regulations are not applicable to this study. It should be noted, however, that regulations regarding direct utilization of resources on BLM lands are not defined at this time.

3.4.2 State Laws and Permits

Nevada's geothermal regulations are handled through the State Department of Conservation and Natural Resources, Division of Water Resources. Permits are not required by the developer for drilling shallow temperature gradient holes in non-designated areas if a licensed driller is used. The resource is located in a non-designated area. The driller must file a card with the division notifying the state of his intention to drill. The shallow exploratory holes must be plugged upon abandonment with neat cement or high grade bentonite drilling muds designed for plugging abandoned wells. Upon plugging, the driller must notify the Division of Water Resources in writing. A permit from the state is required for drilling production wells on both designated and non-designated lands. The process takes a maximum of eight months.

The State of Nevada treats all geothermal fluids as water, and geothermal rights are acquired through the same procedures as when appropriating water rights. In accordance with the Geothermal Steam Act, which specifies that federal leasing and exploration regulations must conform to state laws, even on BLM lands in Nevada the water comes under the control of state water laws.

There are specific regulations in the state water laws pertaining to drilling producing water wells within $\frac{1}{4}$ mile of rivers, wherein casing cannot be perforated above 100 ft. This regulation may be applicable to this site which is located close to a major Nevada river and has been taken into consideration in the preliminary well design.

3.4.3 Local Laws and Permits

There are no city or county permits required for drilling or for construction of a geothermal facility at this time. However, a building permit fee may be applicable to specific types of applications.

3.4.4 Environmental Considerations

All potential geothermal developers must meet state Environmental Protection Agency (EPA) standards which are based on federal EPA regulations. As long as there is no hazard component with the waste fluids, disposal will not be regulated by the EPA hazardous waste program.

In the case of Carlin, the 391 to 430 ppm total dissolved solids in the geothermal fluid is quite low and in fact is within drinking standards. It is conceivable that this figure may be higher in fluid from greater depths where groundwater has not diluted the dissolved constituents. However, based on the known chemical composition, the waste fluids may be ponded for evaporation or ponded for cooling and subsequent discharge into the river.

A State Massive Pollutant Disposal into Streams (MPDS) permit is required before disposing the fluids into a state river. At this time, geothermal springs surface in the river and along the banks, causing no apparent ill effects downstream.

The MPDS permit requires a \$100 application fee which is refunded if the permit is determined to be unnecessary or if there is no public hearing. The permitting process takes up to 4 months as follows:

- Copy of permit application to EPA and permit holder for review: 30 days
- Public notice: 30 days
- If any community objection, a public hearing is held: 30 days
- Writing and issuing of permit: 30 days

The process is much shorter if no public hearing is required. The disposed fluids must not exceed the water quality standard of the Humboldt River. The state water quality standards downstream from Carlin are given in Figure 3-7. A newly enacted regulation entitled the "mixing zone concept" enables discharge of fluids of similar water quality into the river discharge zone as long as the discharged fluids do not alter the quality of the river water downstream. A geochemical analysis of the river water at the discharge point is provided with the permit application. In this specific case, the water in the river is already mixed with geothermal fluids at the discharge point, and fluid disposal to the river may be permitted if the river water at that point has up to a maximum of 430 ppm total dissolved solids. Based on known geothermal water chemistry, there appear to be no objectionable constituents in the Carlin Hot Springs water that would preclude disposal of cooled fluids to the river.

Control Point
At Palisade Gage

May to October Single Value	Not more than 24
November to April Single Value.	Not more than 11
Maximum allowable temperature increase above receiving	

Maximum allowable temperature increase between upstream control point to Palisade: 2°C May to October, 1°C November to April

Annual Average.		.Within range 7.8 - 8.3
Single Value.		.Within range 7.0 - 8.5
ΔpH		.±0.5 pH units

Average (May through October)	Not less than 7.0
Single Value.	Not less than 5.0

Annual Average.	Not more than 3.0
Single Value.	Not more than 4.0

Annual Average.	Not more than 21
Single Value.	Not more than 30

Annual Average.	Not more than 0.40
Single Value.	Not more than 0.55

Annual Average.	Not more than 1.0
Single Value.	Not more than 1.5

Annual Average.	Not more than 350
Single Value.	Not more than 400

Color - No color which will adversely affect the beneficial uses of the water.

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3.4.5 Summary of Licenses, Permits

Figure 3-8 outlines the permits and licenses applicable specifically to development of the Carlin geothermal resource for a space heating project. It is conceivable that within the period required to manifest initiation of the project, new regulations and/or permits and licenses may come into existence. Therefore, the licensing and permitting process should be reviewed when the project is initiated.

No permit is required for ponding the fluids, but ponding will be subject to approval by the landowner. The Carlin sewage system is a septic tank, so fluid disposal to the sewer system cannot be considered.

3.5 Barriers

Some of the barriers to development of the Carlin geothermal potential may be:

- Unreasonable demands by landowners or inability to negotiate leases.
- Raising exploration funding and/or facility funding.
- Homeowners' reluctant to convert to geothermal energy.
- Unfavorable economics.
- Unfavorable environmental circumstances.

Since the springs are on private land, the possibility exists that the landowners may not wish to lease their water rights for this project. Prior to exploration planning the landowners should be contacted to see if they are receptive to the idea.

The fund raising may be the most difficult aspect of the program, especially for leases and exploration involving high risk money. If the resource is capable of supporting the space heating project there will be many possibilities for financing the facility. Carlin is financially sound, but it is not capable of assisting in the funding of the exploration or facility.

Because it would have been premature, homeowners near the springs were not interviewed to determine whether they would be receptive to converting from natural gas to geothermal heat. However, citizens who were interviewed had a generally cooperative attitude and expressed interest in a project for geothermal development. If the economics are favorable and long term savings using geothermal space heating can be demonstrated, homeowners will probably participate in the project.

Unfavorable economics in the final plan could postpone development of the resource. The preliminary economics look good for the model in this study, but unforeseen engineering and development problems may alter the financial attractiveness of the project considerably.

Environmental considerations may create an unfavorable developmental climate. Although the land is privately owned, there are constraints on the type of fluid that can be discharged into the river, based on the chemical composition of the fluid. If subsurface water is highly mineralized, the water may have to be treated before disposal. Environmental aspects are discussed in detail in Section 3.4.4.

Most of these barriers may only delay development. At this time, it is not anticipated that any insurmountable barriers exist.

**Drilling Shallow
Gradient Holes**

Licensed Driller notifies the state by postcard of intent to drill shallow holes.

Upon completion, copies of logs from wells are sent to state water resources division.

Production Wells

Apply for permit from state water resources division. Takes approximately four to six months for approval.

Business License

Apply to City of Carlin town clerk for \$60/year business license. Takes approximately one month or less. May or may not be required according to way heating district is organized.

**Environmental Approval
for fluid disposal, if required**

Apply for MPDS permit to state EPA if fluid disposal is to Humboldt River after cooling. \$100 application fee; takes 4 months if public hearing is necessary.

Figure 3-8 State and Local Licenses, Permits for Development of the Carlin Resource

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Appendices

APPENDIX A

Equations and Calculations for Model Space Heating Project - Heating Requirements in Figure 3-2

The Equations

Maximum Heat Load:

$$HL_{\max} = 500 (t_1 - t_0) = \text{BTU/hr} \quad (1)$$

where 500 = peak load in BTU/hr per degree design temperature, t_0 = outside design temperature, t_1 = inside design temperature.

Annual Heat Load:

$$HL_a = 12,000 (DD) = \text{BTU/yr} \quad (2)$$

where 12,000 is requirement in BTU/DD for an energy efficient home and DD represents total degree F days per year.

Delivered Heat:

$$H = 1.25 (HL_{\max}) = \text{BTU/hr} \quad (3)$$

where 0.25 represents 25 percent overdesign of the heating system.

Fluid Flow Rate:

$$w = H/500 (\Delta t) = \text{gpm} \quad (4)$$

where w is the fluid flow rate in gallons per minute (gpm) and Δt is assumed to be a 20°F fluid temperature drop.

$$\text{Number of Homes} = \frac{\text{gpd available from resource}}{\text{gpd/home required}} \quad (5)$$

Annual Utilization Factor:

$$AN = \frac{DD}{365 \times \Delta T}$$

where DD is degrees F days (6,788) and $\Delta T = t_1 - t_0$, inside design temperature minus outside winter design temperature, $[70 - (-13)] = 83^\circ\text{F}$

APPENDIX A - Continued)

The Calculations

(1) $HL_{\max} = 500 \text{ BTU/hr } [70 - (-13)] = 41,500 \text{ BTU/hr}$

where the inside temperature is assumed to be 70°F and outside temperature of -13°F is representative for the normal wintertime lows in the Carlin Area.

(2) $HL_a = 12,000 \text{ BTU/DD} \times 6,788 \text{ DD} = 8.15 \times 10^7 \text{ BTU/yr}$

Degree F days are from Table 1-6 (this report)

(3) $H = 1.25 (41,500 \text{ BTU/hr}) = 51,875 \text{ BTU/hr}$

(4) $w = \frac{51,875 \text{ BTU/hr}}{500 \text{ BTU/hr (20°F)}} = 5.2 \text{ gpm or } 7,488 \text{ gpd}$

(5) Fluid flow at 170°F = 300 gpm or 432,000 gpd:

$$\frac{432,000 \text{ gpd}}{7,488 \text{ gpd/home}} = 58 \text{ homes, say } 60 \text{ homes}$$

APPENDIX B

Equations for Determination of Pump Sizes

Downhole Pump Selection

$$hp = \frac{8.34 \times 100 \text{ ft} \times 300 \text{ gpm}}{33,000 \times 0.85}$$

where 8.34 is gallons of water per pound, 100 ft is pumping fluid level, 300 gpm is flow, 33,000 is ft-lbs per minute per horsepower, and 0.85 is the pump efficiency.

Circulating Pump Selection

$$hp = 300 \text{ gpm} \times (59 + 115.6 \text{ ft}) \times \left\{ \frac{8.34 \text{ gal/lb}}{33,000 \text{ ft-lbs/min/hp} \times 0.85} \right\}$$

where $59 \text{ ft} = 1.4 \text{ mi} \times 5,280 \text{ ft/mi} \times \left\{ \frac{0.8 \text{ ft}}{100 \text{ ft}} \right\}$

and 0.8 represents friction loss of 0.8 ft per 100 ft; 115.6 ft represents the additional 50 psi desired at the end of the primary pipeline for the distribution to homes as follows:

$$115.6 \text{ ft} = \frac{50 \text{ psi} \times 34 \text{ ft water/atm}}{14.7 \text{ psi/atm}}$$

where 14.7 is psi per atmosphere and 34 is ft of water (at 4°C) per atmosphere.

APPENDIX C

Equations and Calculations for Capital Costs, Annual Costs

Pump Costs: $(12.5 \text{ hp} \times 350/\text{hp}) + \$50 = \$4,425$
 $20.0 \text{ hp} \times 100/\text{hp} = \$2,000$

Supply Pipe: $\$16/\text{ft} \times 2 \text{ mi} (5,280 \text{ ft/mi}) = \$168,960$

Annual Capital Costs amortized over 30 yrs:

$$= \frac{Pi(1+i)^n}{(1+i)^n - 1}$$

where P = principal (capital costs), i = interest rate at either 10 or 13 percent
and n = number of years debt is financed.

Pump Operating Costs:

$\$/\text{kwh} \times \text{hp} \times 0.7457 \times 8,760 \times \text{AN}$ where $\$/\text{kwh} = 0.06$, hp is 32.5 for Case 1 and 20 for Case 2, 8,760 is total hours/yr, AN is the utilization factor (Appendix A), and 0.7457 is kilowatts/hp. The calculated annual cost normally assumes a year-around operating cost while the actual heating season is approximately 7 months. Therefore, costs in this study reflect the annual heating season only.

APPENDIX D

Present Worth Evaluation Calculations

Extractable Heat in Therms:

$$\begin{aligned} \text{BTU/yr available} \times \text{AN} &= \text{BTU/yr useable} \\ \text{or } 5.6 \times 10^{10} \text{ BTU/yr} \times 0.22 &= 1.23 \times 10^{10} \text{ BTU/yr} \end{aligned} \quad (1)$$

where 5.6×10^{10} BTU/yr is estimated from EG&G (1978) estimates for a 300 gpm resource at 170°F and AN is the utilization factor (see Appendix A).

$$\frac{1.23 \times 10^{10} \text{ BTU/yr}}{1 \times 10^5 \text{ BTU/Therm}} = 1.23 \times 10^5 \text{ T/yr} \quad (2)$$

Natural Gas Annual Cost for Useable Volume of Geothermal Heat:

$$1.23 \times 10^5 \text{ T/yr} \times \$/\text{T (delivered)} = \$/\text{yr calculated for each year} \quad (3)$$

APPENDIX E

Requirements for GLGP Loan Application

Borrower/Management

Borrower's legal existence and structure, and management's experience, so as to demonstrate its ability to complete the project in a timely manner and repay the guaranteed loan. An organizational chart of the borrower and resumes of the management team associated with the project are important. The qualifications of outside consultants that are part of the project will be needed.

Geothermal Resource

Detailed data concerning the geothermal resource should contain information on temperature, chemical makeup and flow rate. The information should be of sufficient makeup so as to determine the potential production capacity and the type of equipment needed to convert the resource into energy. Data as to the expected geothermal resource life is essential.

Environmental Data

Information concerning the environmental aspects of the project is to be of sufficient material to demonstrate that the project will have no adverse effect on the environment. This information is to include an analysis of the environmental impact for the ultimate project scope, i.e., a power plant site for a field development project.

Marketability

Supportive information to demonstrate that there will be satisfactory markets to sell the end product of the project at a price sufficient to cover operations, repay the guaranteed loan and allow a reasonable profit on the borrower's investment.

Project Plan

A descriptive plan is needed to demonstrate how the geothermal resource and facilities will be developed, the time frame involved and when production will be on stream. Included will be a "milestone schedule" that will reflect the borrower's potential goals that are to be achieved during each milestone. This should include a minimum goal achievement for each milestone, which if not achieved, would require a complete re-evaluation of the project at that point.

Financial Information

Financial data will pertain to the borrower and the project. The borrower's financial information will include an audited financial statement for the previous three years of operation. A current interim financial report, prepared by the financial management of the borrower is to be included if the latest fiscal statement is not current. The project financial information will consist of three

APPENDIX E (Continued)

parts; the borrower's cost pertaining to the project prior to loan funding, a use of funds schedule over the development phase of the project loan and the borrower's equity funds, (tied into the "Milestone Schedule") and a projected cash flow statement reflecting the future economic performance. The financial data pertaining to the project is to be detailed in a manner so that the lender and DOE can satisfy themselves as to the project's feasibility.

Security

The borrower to present a schedule of assets that will be used to support the loan. This schedule will pertain to those assets that are presently in the project and those that will be acquired during the project development phase.

Legal

Supportive documentation is required pertaining to the legal existence of the borrower, its interest in the property to be developed, and those contracts that are an essential part of the project. This information should contain data on the insurance coverage concerning the project. Also a separate schedule pertaining to significant litigation is needed. At the time the project loan is ready to be funded, the borrower is to furnish the appropriate permits to proceed and express authorities of those authorized to act for the borrower.

From Woods, John H., 1978

APPENDIX F

Directory of Contacts for Federal Financial Programs - Alternate Energy Incentive Projects.

DOE Geothermal Loan Guaranty Program (GLGP)

U.S. Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, California 94612

Ken Bomberg
(415) 273-7151

Program Research & Development Announcements (PRDA) Program Opportunity Notice (PON)

U.S. Department of Energy
San Francisco Operations Office
1333 Broadway
San Francisco, California 94612

Hilary Sullivan
(415) 273-7943

Geothermal Energy Technical Assistance Program

Nevada Department of Energy
400 West King Street
Carson City, Nevada 89710

Kelly Jackson
(702) 885-5157

User Coupled Drilling Program

U.S. Department of Energy
Idaho Falls, Idaho 83401

Sue Prestwich
(208) 526-1147

National Energy Conservation Policy Act Grants

U.S. Department of Energy
20 Massachusetts Avenue NW
Room 4117
Washington, D.C. 20545

Michael Willingham, Director
Office of State - Specific Programs
(202) 376-4149

HUD Programs

U.S. Department of Housing
& Urban Development
One Embarcadero Center
Suite 1600
San Francisco, California 94111

Small Business Administration

Small Business Administration
3030 North Central Avenue
Phoenix, Arizona 85012

(602) 261-3611